Climate Change Trends for Planning at Abraham Lincoln Birthplace National Historical Park, Kentucky

Prepared by Nicholas Fisichelli, NPS Climate Change Response Program June 3, 2013

Climate Change and National Parks

Climate change, in conjunction with other stressors, is impacting all aspects of park management from natural and cultural resources to park operations and visitor experience. Effective planning and management must be grounded in our comprehension of past dynamics as well as the realization that future conditions may shift beyond the range of variability observed in historical data. Climate change will manifest itself not only as shifts in mean conditions (e.g., increasing mean annual temperature) but also as changes in climate variability (e.g., more intense storms and droughts). Put another way, land managers are dealing with both rapid directional change and tremendous uncertainty. Understanding climate change projections and associated levels of uncertainty will facilitate planning actions that are robust regardless of the precise magnitude of change experienced in the coming decades.

Historical and Projected National and Regional Climate Trends

Text and figures in this section are directly from the draft National Climate Assessment (NCADAC 2013; http://ncadac.globalchange.gov/)

Historical Temperature Trends

"U.S. average temperature has increased by about 1.5°F since record keeping began in 1895; more than 80% of this increase has occurred since 1980 (Figure 1). The most recent decade was the nation's warmest on record and U.S. temperatures are expected to continue to rise. Because human-induced warming is superimposed on a naturally varying climate, the temperature rise has not been, and will not be, smooth across the country or over time… The cooling in mid-century that was especially prevalent over the eastern half of the U.S. may have stemmed partly from the cooling effects of sulfate particles from coal burning power plants (Leibensperger et al. 2012), before these sulfur emissions were regulated to address health and acid rain concerns... Since 1991, temperatures have averaged 1°F to 1.5°F higher than 1901-1960 over most of the U.S., except for the Southeast, where the warming has been less than 1°F. On a seasonal basis, long-term warming has been greatest in winter and spring."

Historical Precipitation Change

"Precipitation averaged over the entire U.S. has increased during the period since 1900 (+5%), but regionally some areas have had increases greater than the national average, and some areas have had decreases (Figure 1). The largest increases have been in the Midwest, southern Great Plains, and Northeast. Portions of the Southeast, the Southwest, and the Rocky Mountain states have experienced decreases."

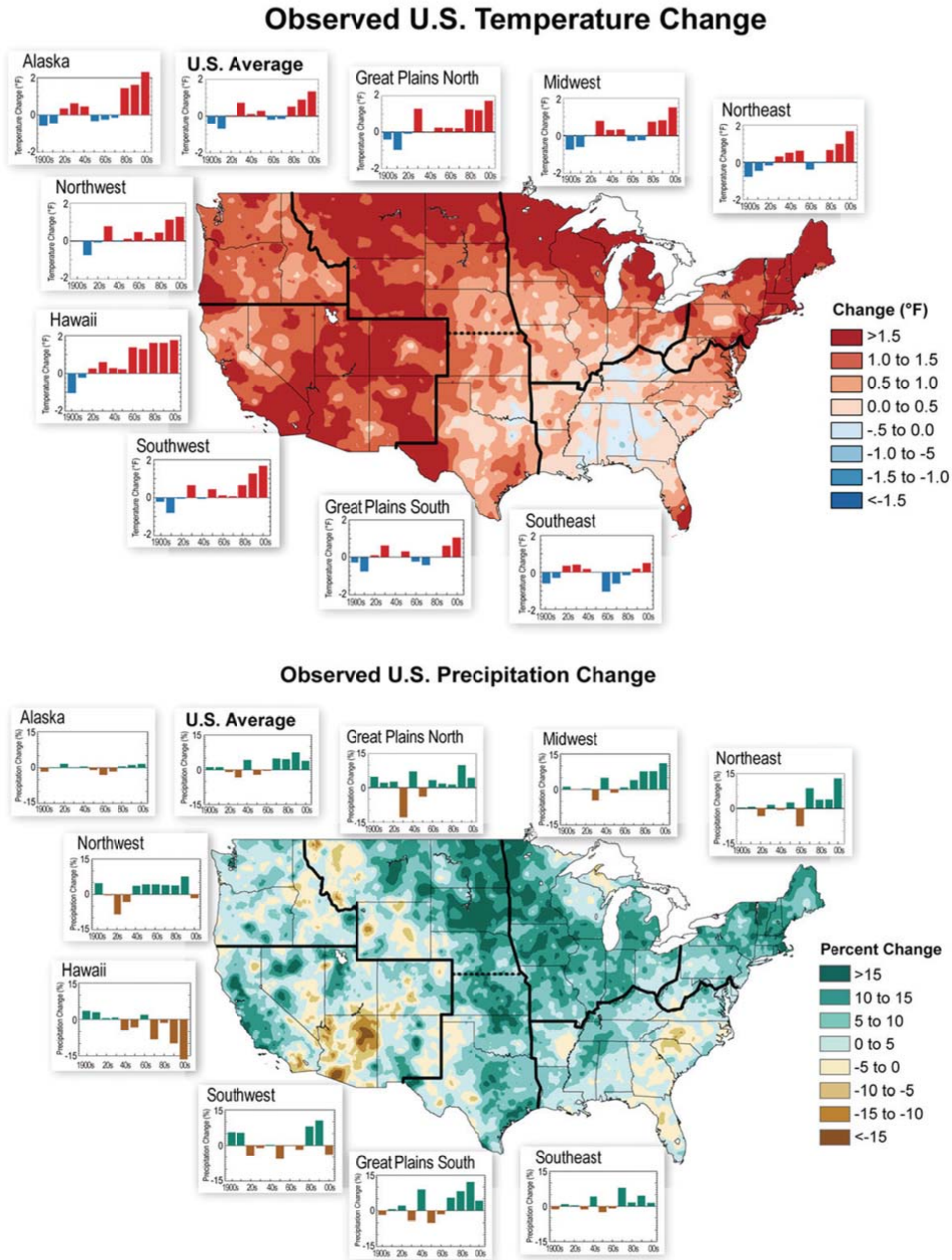

Figure 1. Observed U.S. temperature and precipitation changes. The colors on the maps show changes over the past 20 years (1991-2011) compared to the 1901-1960 average. The bars on the graphs show the average changes by decade for 1901-2011 (relative to the 1901-1960 average) for each region. The period from 2001 to 2011 was warmer than any previous decade in every region. (Figure source: NOAA NCDC / CICS-NC. Data from NOAA NCDC.)

Projected 21st Century Temperature Change

Warming patterns of the past several decades are projected to continue across the entire country. "In the next few decades, this warming will be roughly 2°F to 4°F in most areas. By the end of the century, U.S. warming is projected to correspond closely to the level of global emissions: roughly 3°F to 5°F under lower greenhouse gas emissions scenarios (B1) involving substantial reductions in emissions, and 5°F to 10°F for higher emissions scenarios (A2) that assume continued increases in emissions (Figure 2). The largest temperature increases are projected for the upper Midwest and Alaska." (It is important to note that the recent trajectory of atmospheric greenhouse gas emissions is above that of the A2 higher emissions scenario (Friedlingstein et al. 2010).)

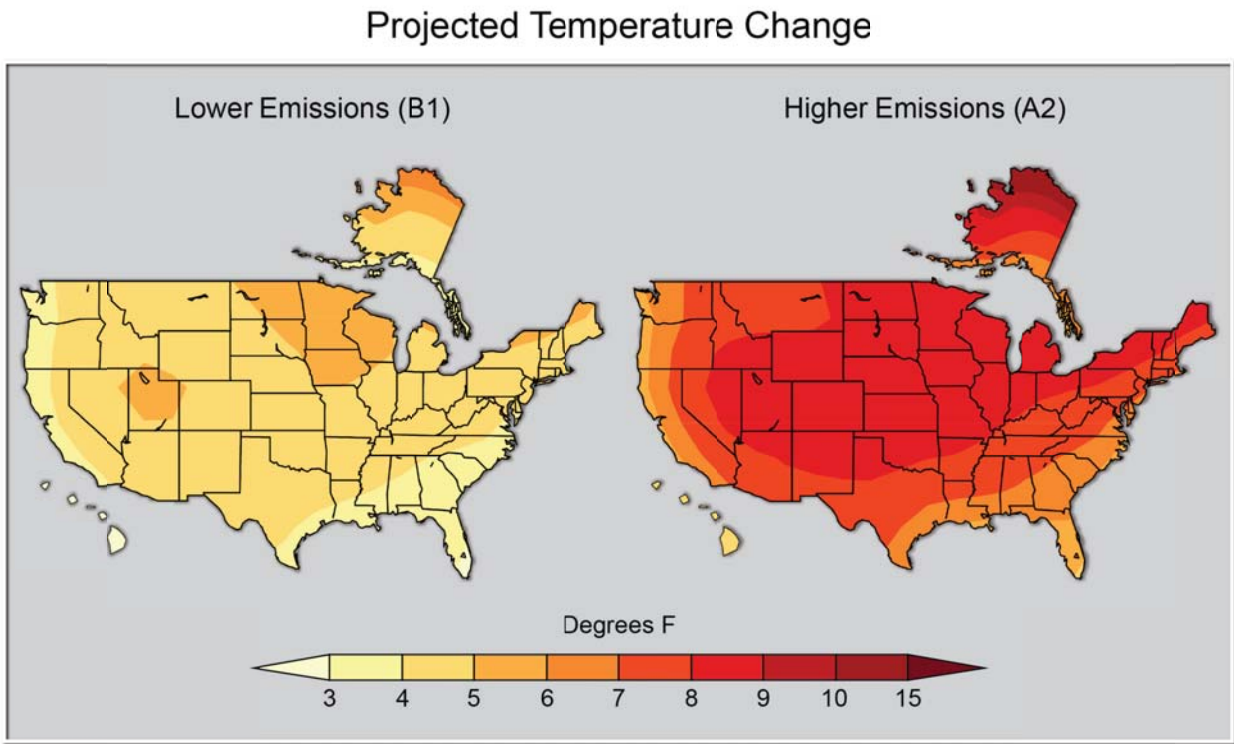

Figure 2. Projected Temperature Change. Maps show projected change in average surface air temperature in the later part of this century (2070-2099) relative to the later part of the last century (1971-1999) under a scenario that assumes substantial reductions in heat trapping gases (B1, left) and a higher emissions scenario that assumes continued increases in global emissions (A2, right). Projected changes are averages from 15 CMIP3 models for the A2 scenario and 14 models for the B1 scenario. (Figure source: adapted from (Kunkel et al. 2012).)

Projected 21st Century Precipitation Changes

Continuing increases in the emissions of greenhouse gases is projected to alter precipitation patterns across much of North America (Figure 3). "More winter and spring precipitation is projected for the northern U.S., and less for the Southwest, over this century. The projected changes in the northern U.S. are a consequence of both a warmer atmosphere and associated large-scale circulation changes. Warmer air can hold more moisture than colder air, leading to more intense rainfall. The projected reduction in Southwest precipitation is a result of large-scale circulation changes caused by increased heating of the global atmosphere."

"Drier conditions in the summer are projected in most areas of the contiguous U.S, but outside of the Northwest and south-central region, there is generally not high confidence that the changes will be large compared to natural variability. In all models and scenarios, a transition zone between drier (to the south) and wetter (to the north) shifts northward from the southern U.S. in winter to southern Canada in summer. Wetter conditions are projected for Alaska and northern Canada in all seasons."

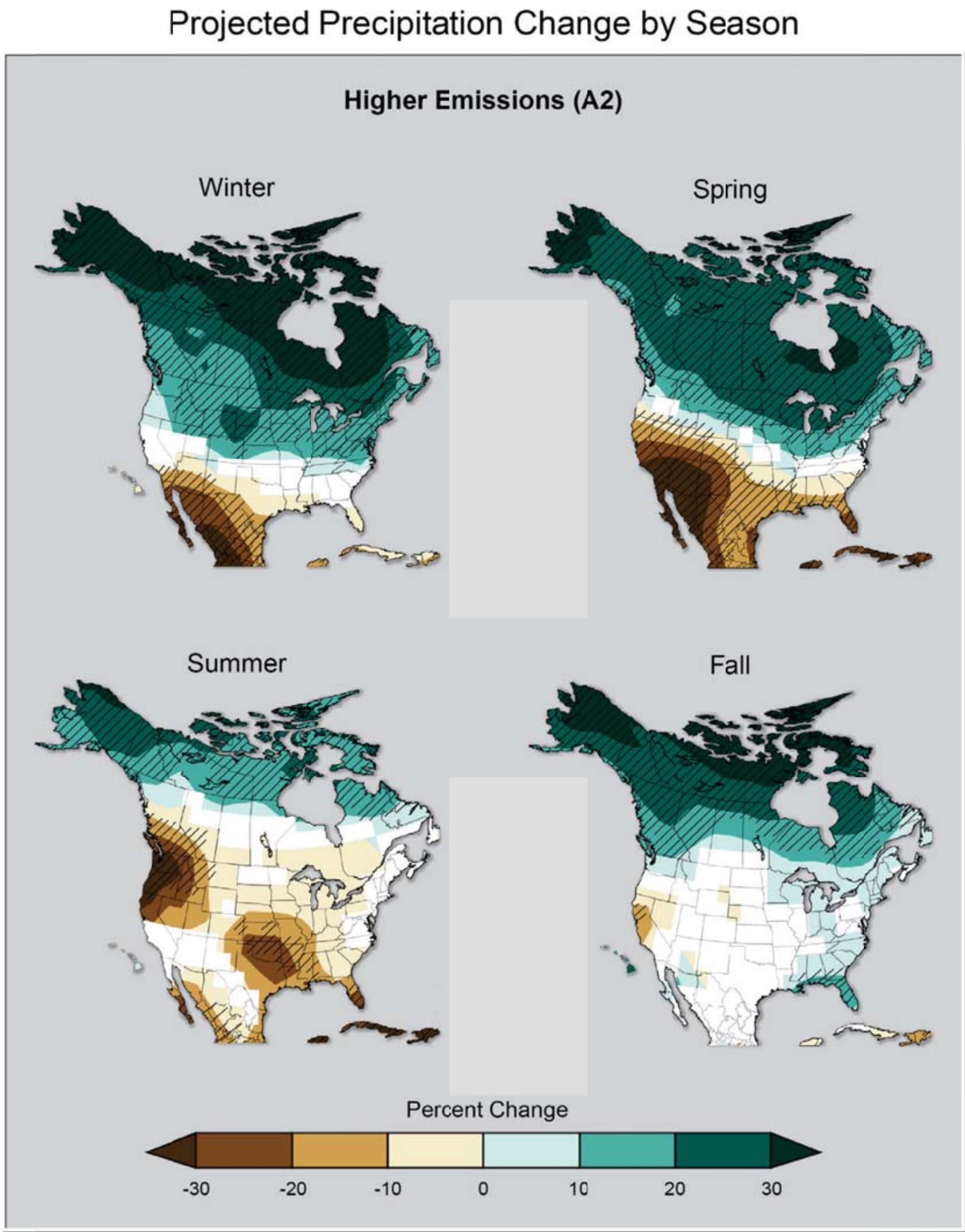

Figure 3. Projected percent change in seasonal precipitation for 2070-2099 (compared to the period 1901-1960) under an emissions scenario that assumes continued increases in emissions (A2). Teal indicates precipitation increases, and brown, decreases. Hatched areas indicate

confidence that the projected changes are large and are consistently wetter or drier. White areas indicate confidence that the changes are small. Wet regions tend to become wetter while dry regions become drier. In general, the northern part of the U.S. is projected to see more winter and spring precipitation, while the Southwest is projected to experience less precipitation in the spring. (Figure source: NOAA NCDC / CICS-NC. Data 11 from CMIP3; analyzed by Michael Wehner, LBNL.)

See the draft National Climate Assessment for more in-depth information (NCADAC 2013; http://ncadac.globalchange.gov/)

Historical and Projected Climate Trends for the Region Including Abraham Lincoln Birthplace National Historical Park, Kentucky

Historical climate trends (1893-2012)

Historical climate trends for Abraham Lincoln Birthplace are based on historic climate data from a nearby long-term weather station (Greensburg, KY, station 153430, approximately 25 miles southeast of the park) acquired from the United States Historical Climatology Network (cdiac.ornl.gov). Over the entire 120 year instrumental record (1893-2012) mean annual temperature did not show a statistically significant linear trend ($p = 0.46$); however, since 1960, mean annual temperature has increased at a rate of 0.5 °F (0.3 °C) per decade ($p < 0.0001$; Figure 5). Similarly, seasonal temperatures did not exhibit significant linear trends across the entire 120 year instrumental record, while recent decades suggest increasing temperatures in winter and summer (Figure 6). Annual precipitation showed strong interannual variability and a statistically significantly increasing linear trend (+0.4 inches (10 mm) per decade, $p = 0.04$, Figure 5). Seasonal precipitation showed the strongest increase in fall (+0.26 inches (+6.6 mm) per decade, $p=0.01$; Figure 7).

Future climate projections

Future climate projections for the area including Abraham Lincoln Birthplace National Historical Park are from multi-model averaged data (Kunkel et al. 2013). Mean annual temperature, compared with the 1971-1999 average, is projected to increase 2-3 °F by mid-century and 4-8 °F by the end of the century, depending on the greenhouse gas emissions scenario (Table 1). Current greenhouse gas emissions are on a trajectory above the high (A2) scenario (IPCC 2007, Friedlingstein et al. 2010). Warming by mid-century is projected for all seasons, with the greatest increases likely in summer and fall (Figure 8). There is wide agreement among individual climate models in the direction and magnitude of warming over the coming decades.

Precipitation projections indicate minor changes in annual and seasonal totals over the coming century, with increases in winter and decreases in summer total precipitation (Table 1, Figure 9). Annual and seasonal precipitation by mid-century may increase slightly (0 to +5%), compared with 1971-1999 values; however, precipitation variability is likely to remain large over the coming decades, and there is greater uncertainty in precipitation than temperature projections (Kunkel et al. 2013).

In addition to warmer mean temperatures and changes in total precipitation, climate change will manifest itself in many other ways. This includes more frequent heat waves, droughts, floods, and an extended frost-free season. The number of days with maximum

temperatures > 95 °F and the length of the frost-free season are both projected to increase by 20-30 days/year (high (A2) emissions scenario 2041-2070 compared with 1980-2000; Kunkel et al. 2013). Small changes in total annual precipitation may mask large shifts in the precipitation regime and associated impacts to ecosystems. The annual maximum number of consecutive days with rainfall less than 0.1 inches may increase by a few days while the annual number of days with heavy rainfall (> 1 inch) is projected to increase by 15 to 20 days (high (A2) emissions scenario, 2041-2070 compared with 1980-2000; Kunkel et al. 2013). Heavier rain events and an increased number of days between rain events will lead to both more frequent droughts and more severe flooding and erosion.

Table 1. Projected annual temperature and precipitation changes for the Abraham Lincoln Birthplace National Historical Park area for three future time periods compared with the 1971-1999 average. Two greenhouse gas emissions scenarios are presented, the low (B1) and high (A2) scenarios (IPCC 2007). Projected changes are based on multi-model means from 14-15 CMIP3 climate models. (Data from Kunkel et al. 2013, see Figures 26, 37).

Temperature Difference from 1971-1999

	Greenhouse Gas Emissions Scenario		Confidence in
Years	Low (B1)	High A2	Projection
2021-2050	+2 °F	+3 °F	High
2041-2070	+3 °F	+5 °F	High
2070-2099	+4 °F	+8 °F	High

Precipitation Difference (%) from 1971-1999

	Greenhouse Gas Emissions Scenario		Confidence in
Years	Low (B1)	High A2	Projection
2021-2050	0% to +3%	0% to +3%	Medium
2041-2070	0% to +3%	0% to +3%	Low
2070-2099	0% to +3%	0%	Low

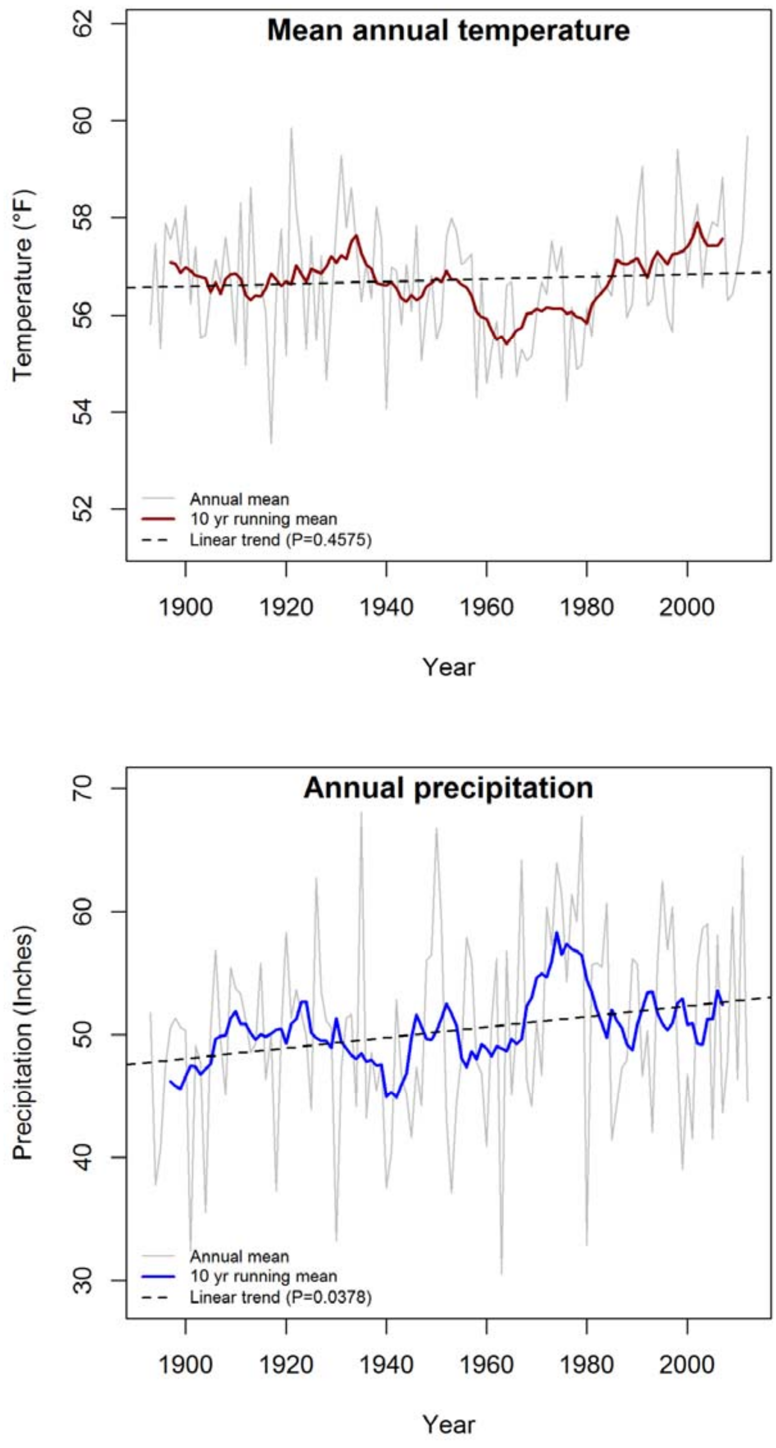

Figure 5. Mean annual temperature and annual precipitation (1893-2012) from the Greensburg, KY long-term weather station (cdiac.ornl.gov).

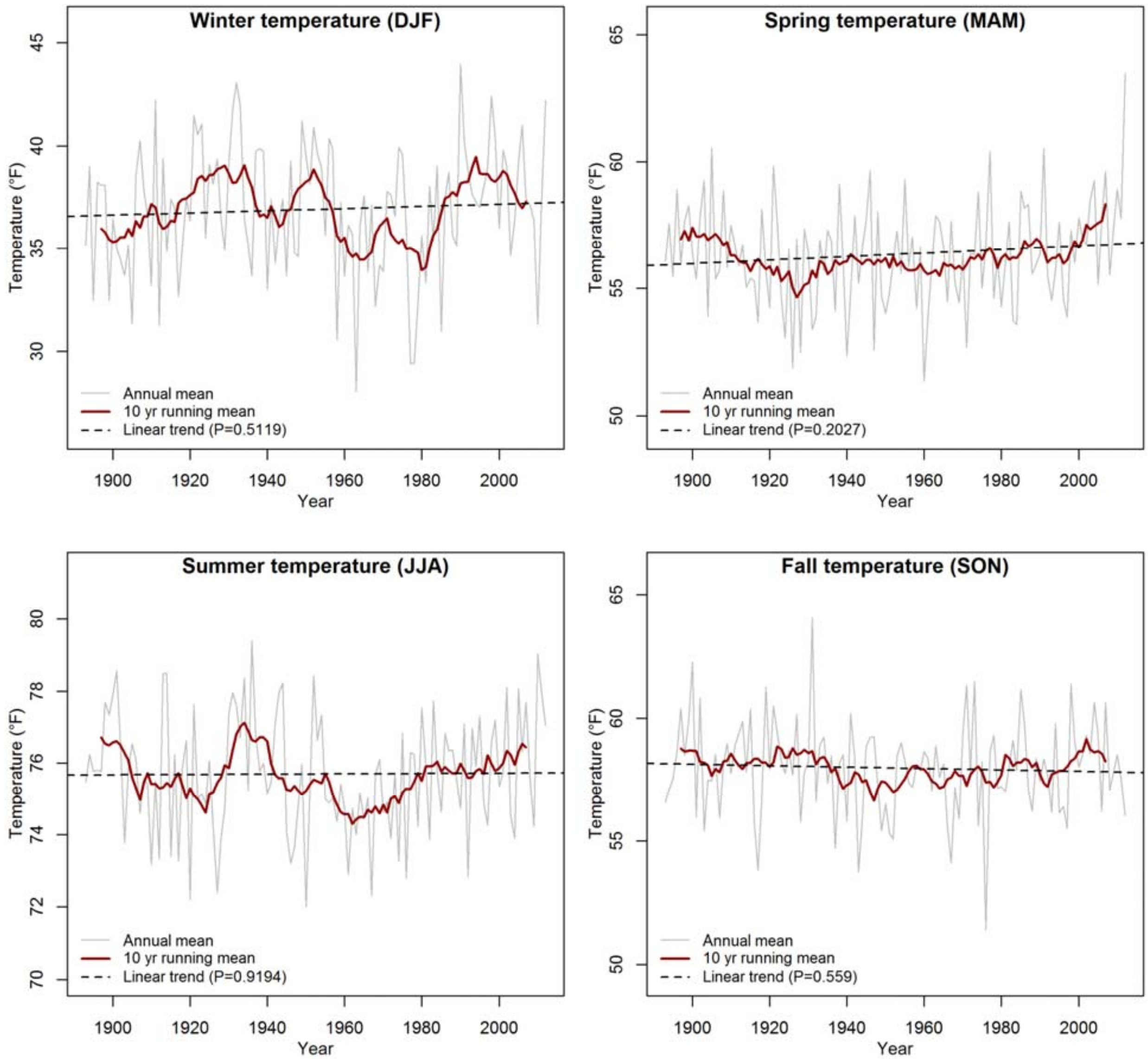

Figure 6. Seasonal temperature trends (1893-2012) from the Greensburg, KY long-term weather station (cdiac.ornl.gov).

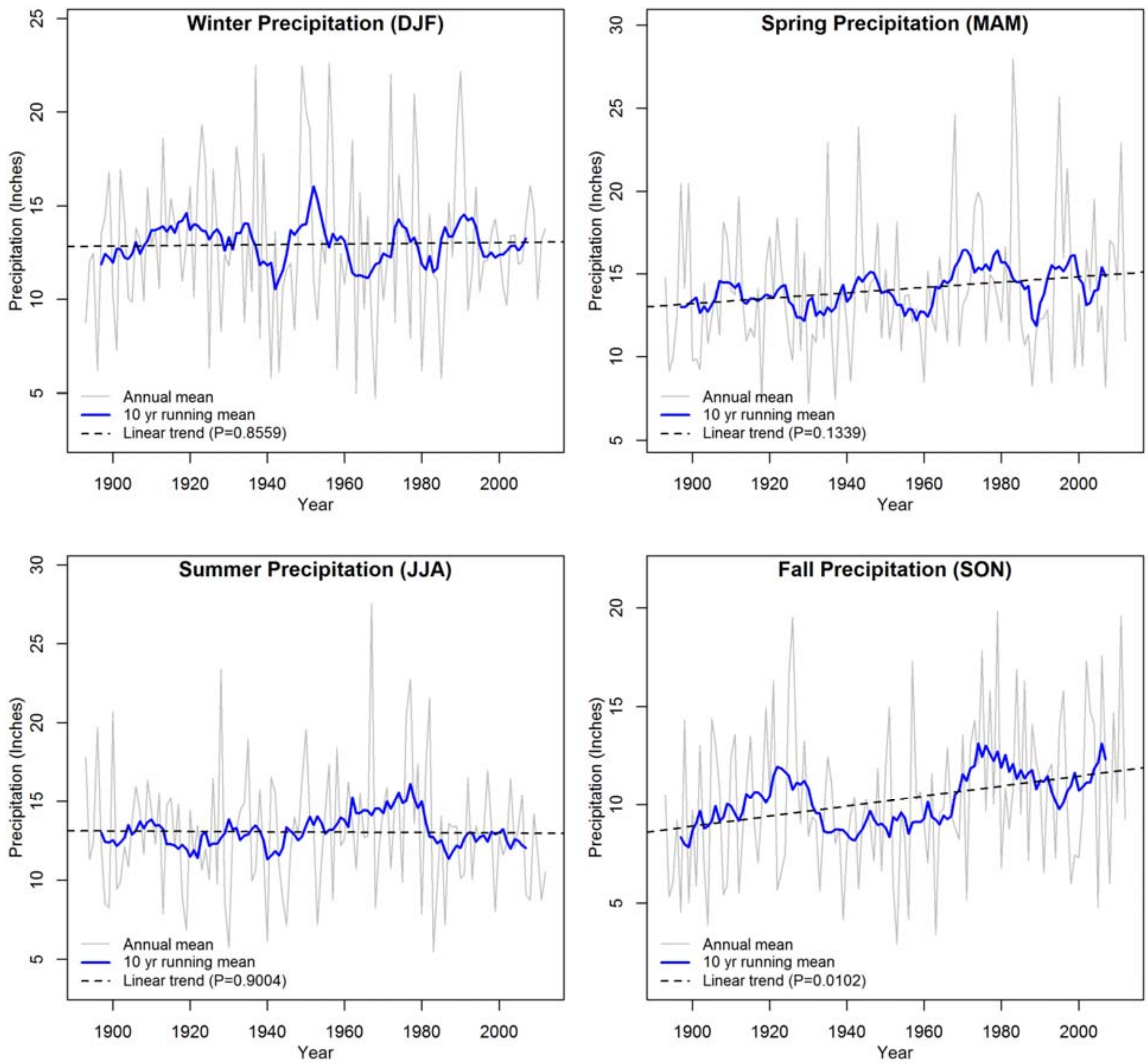

Figure 7. Seasonal precipitation trends (1893-2012) from the Greensburg, KY long-term weather station (cdiac.ornl.gov).

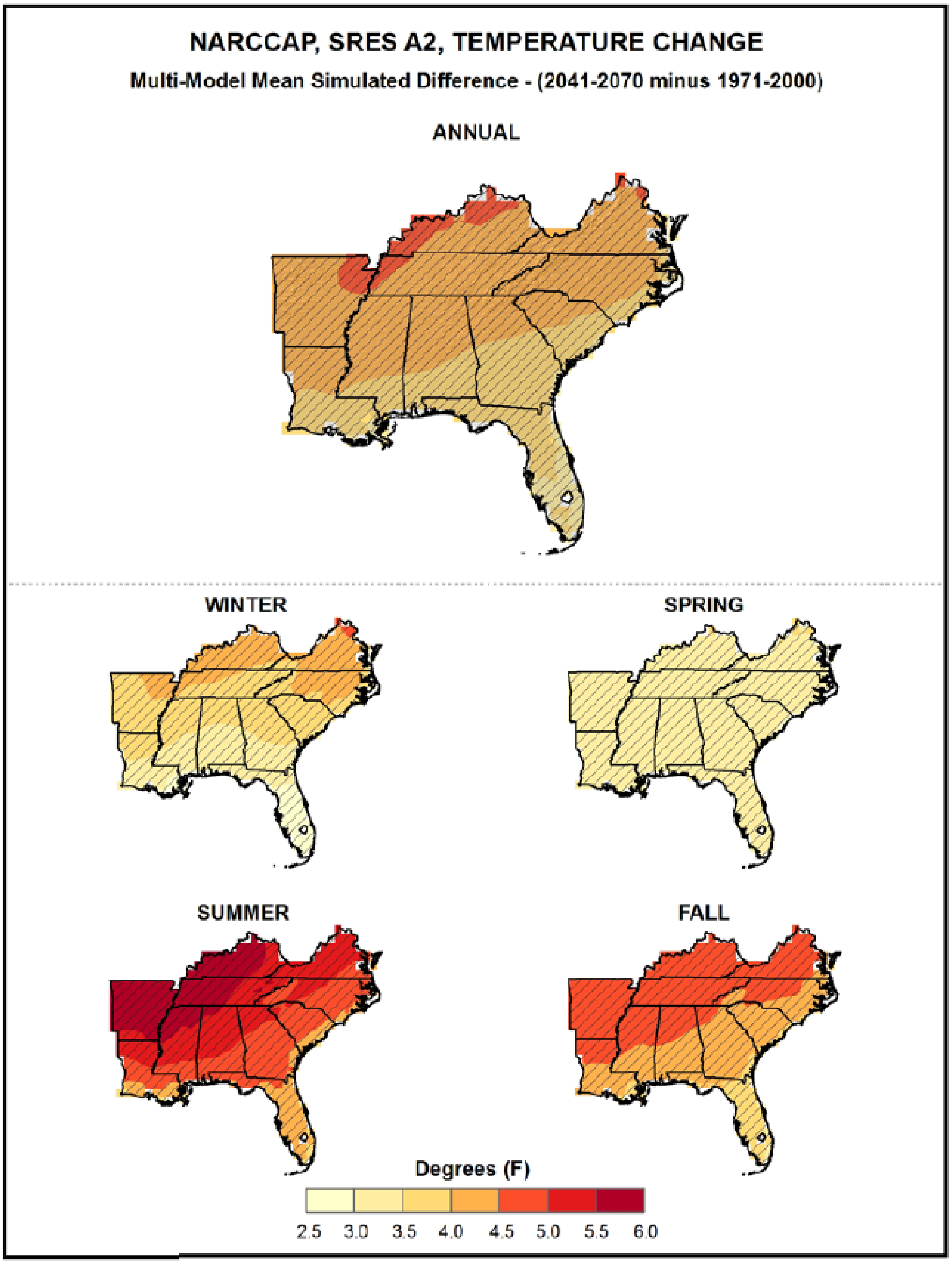

Figure 8. Projected annual and seasonal temperature change. Maps show projected change in average surface air temperature in mid-century (2041-2070) relative to the later part of the last century (1971-2000). Projected changes are averages from 11 NARCCAP regional climate simulations for the high (A2) CO_2 emissions scenario. Color with hatching indicates that more that 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change. Figure and legend from Kunkel et al. (2013).

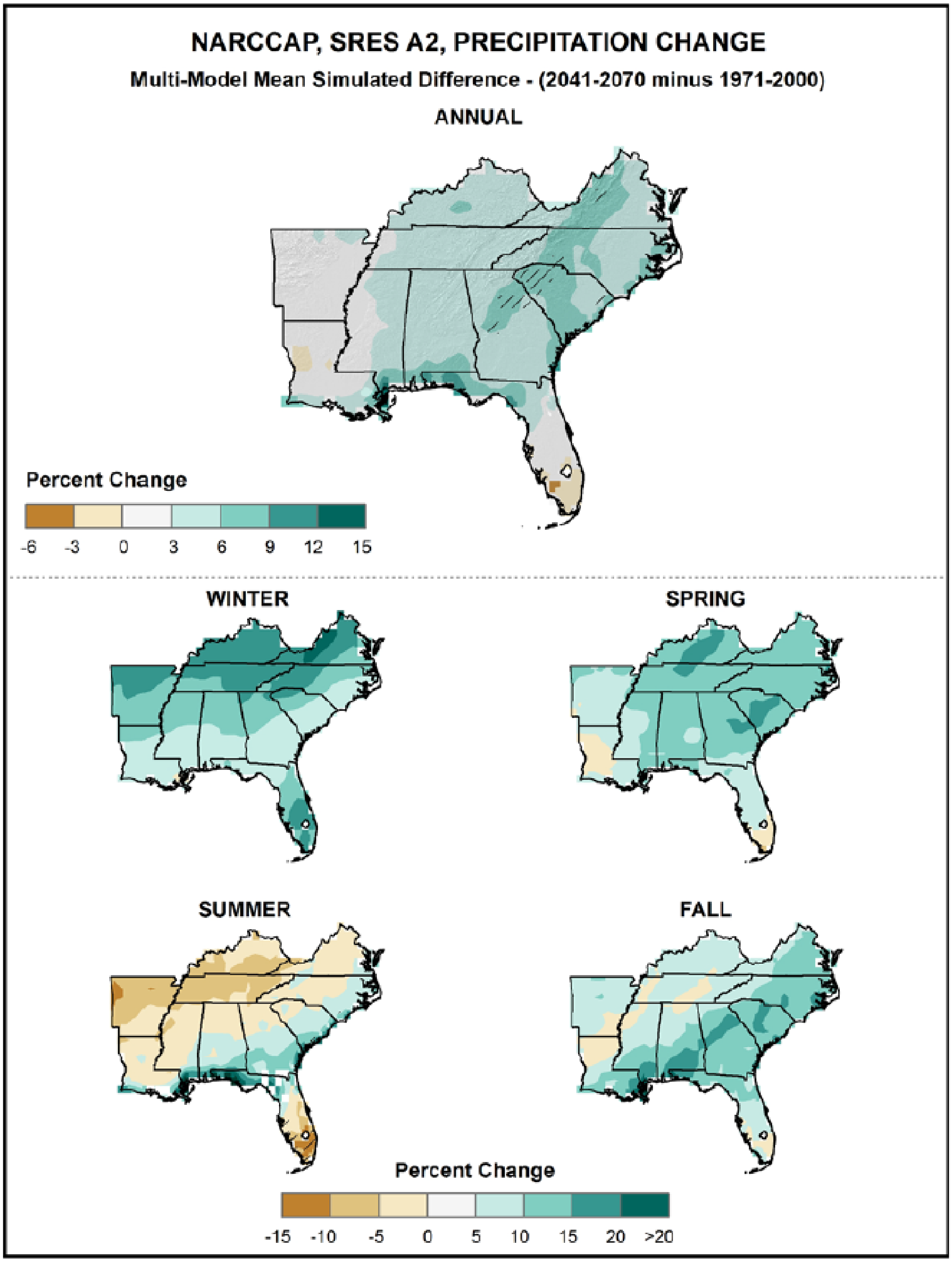

Figure 9. Projected annual and seasonal precipitation change. Maps show projected change in precipitation for mid-century (2041-2070) relative to the later part of the last century (1971-2000). Projected changes are averages from 11 NARCCAP regional climate simulations for the high (A2) CO_2 emissions scenario. Color only indicates that less than 50% of the models show a statistically significant change in precipitation. Color with hatching indicates that more that 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change. Figure and legend from Kunkel et al. (2013).

References

Friedlingstein P., R. Houghton, G. Marland, J. Hackler, T. A. Boden, T. Conway, J. Canadell, M. Raupach, P. Ciais, and C. Le Quéré. 2010. Update on CO_2 emissions. *Nature Geoscience* 3:811-812.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK.

Kunkel, K.E., L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, and J.G. Dobson. 2012. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 9. Climate of the Contiguous United States.

Kunkel, K.E., L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, M.C. Konrad II, C.E., Fuhrman, B.D. Keim, M.C. Kruk, A. Billet, H. Needham, M. Schafer, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 2. Climate of the Southeast U.S. National Oceanic and Atmospheric Administration Technical Report NESDIS 142-2, Washington, DC.

Leibensperger, E.M., L.J. Mickley, D.J. Jacob, W.T. Chen, J.H. Seinfeld, A. Nenes, P.J. Adams, D.G. Streets, N. Kumar, and D. Rind, 2012: Climatic effects of 1950-2050 changes in US anthropogenic aerosols - Part 1: Aerosol trends and radiative forcing. *Atmospheric Chemistry and Physics Discussions*, **11,** 24085–24125.

National Climate Assessment and Development Advisory Committee (NCADAC). 2013. U.S. National Climate Assessment v. 11 Jan 2013 DRAFT. http://ncadac.globalchange.gov/